T/R Membranes for Large Aperture Scanning Phased Arrays

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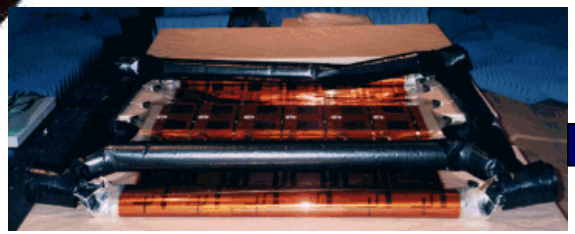
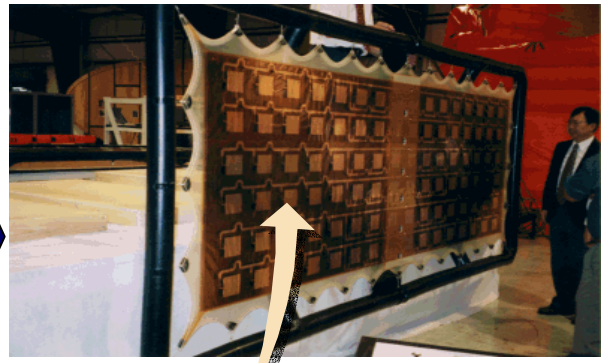
Motivation

Motivation: To develop technologies needed for active membrane phased array antennas for Synthetic Aperture Radar (SAR). This would enable very large spaceborne SAR arrays for mapping, surface monitoring and change detection of Earth from LEO/MEO/GEO (code Y) and other planets (Codes S)

Roll-up SAR Antenna (stowed)



Roll-up SAR Antenna (partially deployed)



Roll-up SAR Antenna (deployed)

Benchmark Current rigid antenna technology cannot be used for very large arrays due to their large mass, size and cost. By developing technologies for active membrane antennas we will not only achieve lighter, lower cost SARs but we can also achieve larger aperture antennas with 2 dimensional beam scanning ability. This will give us capabilities such as instantaneous accessibility and 3-D deformation measurements (i.e. for earthquake and volcanic eruption).

Electronics Integration with Radiating Aperture

Rigid arrays
heavy >20kg/m^2, expensive

Membrane antennas
low mass <2kg/m^2 ,smaller stow volume, lower cost

Challenges

Challenges

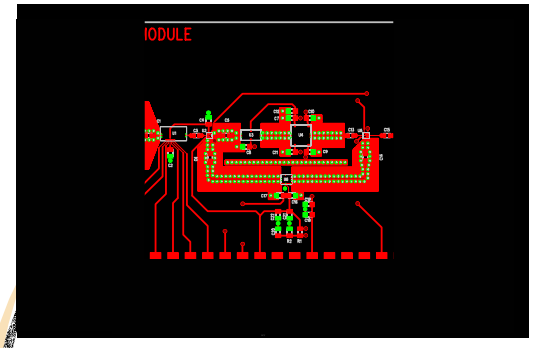
- Lightweight structures
- Membrane aperture
- Integrated electronics
- Thermal management
- Radiation and shielding
- Attachment of electronics
- Interconnects
- Metrology/calibration
- System architecture and integration
- Manufacturability
- Reliability

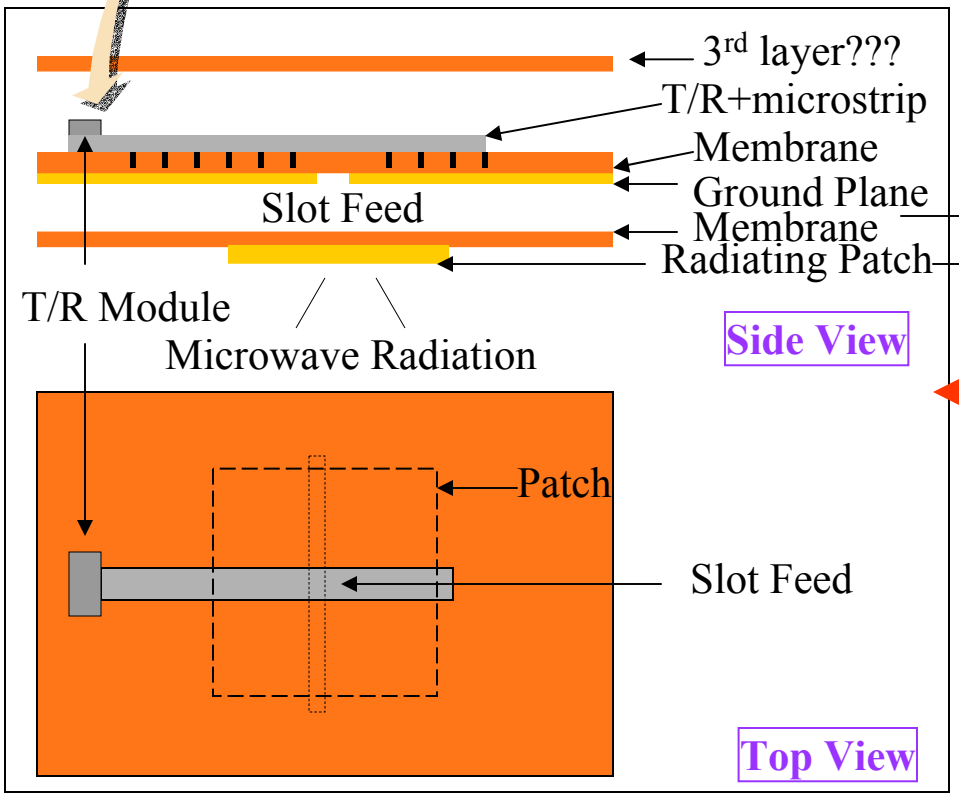
This Work: Flex-compatible T/R (T/R membrane)

- Antenna Architecture
- Antenna Feed
- T/R design
- Packaging/Attachment
- Thermal Management

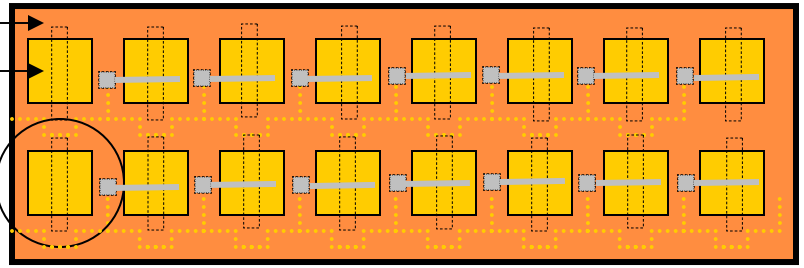
T/R Architecture – Microstrip Feed

T/R module circuit



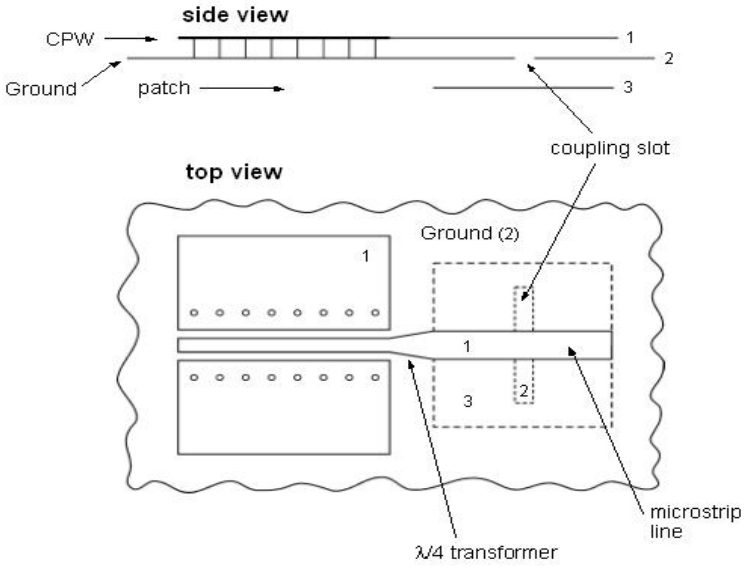


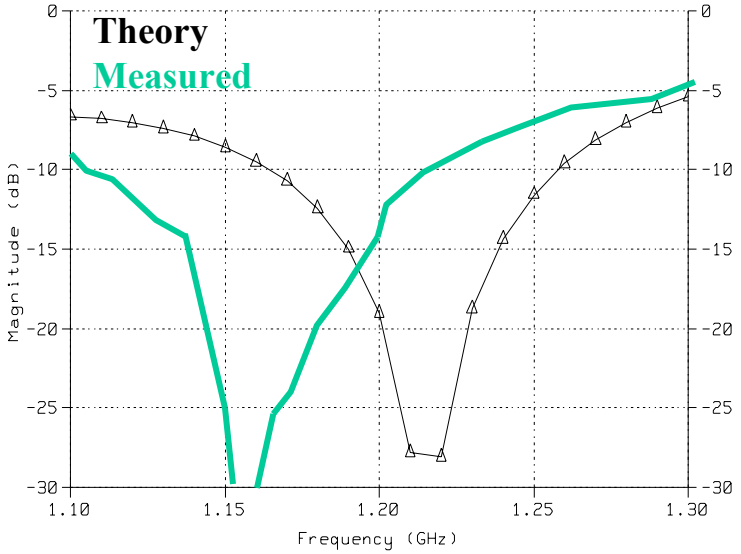
A 2x8 section of the membrane antenna



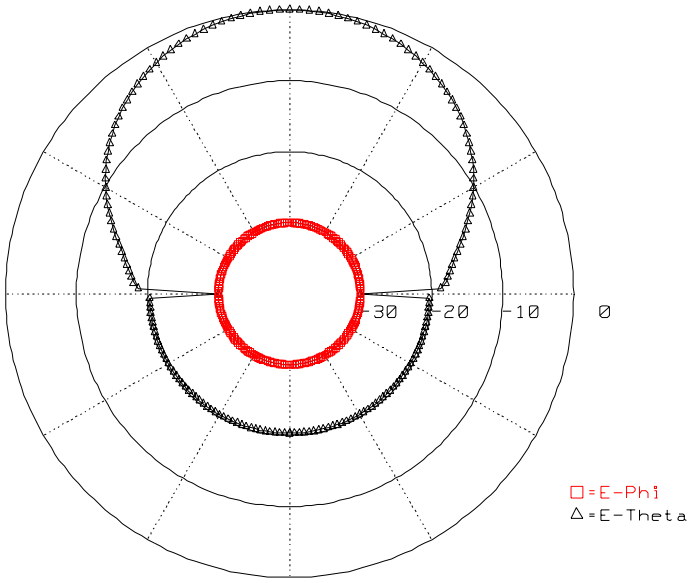
Kapton thickness: 2mils
Copper thickness: 5 - 12um
Layer spacing: 1.25cm

Coupling to Patch Via Microstrip Feed

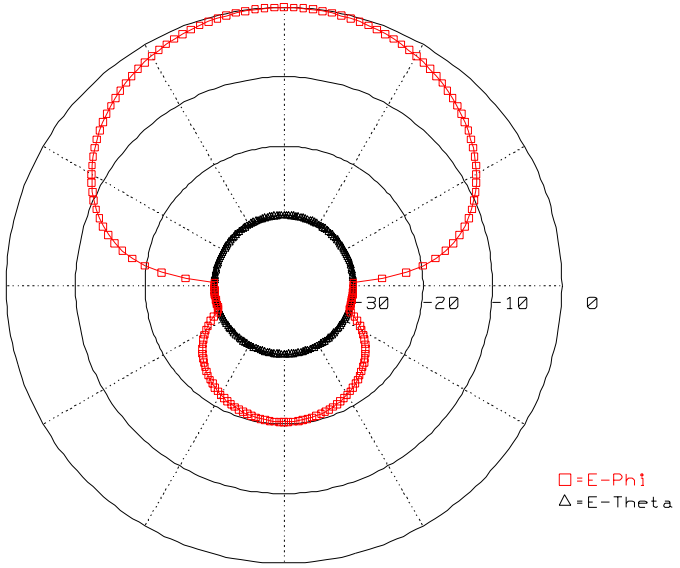




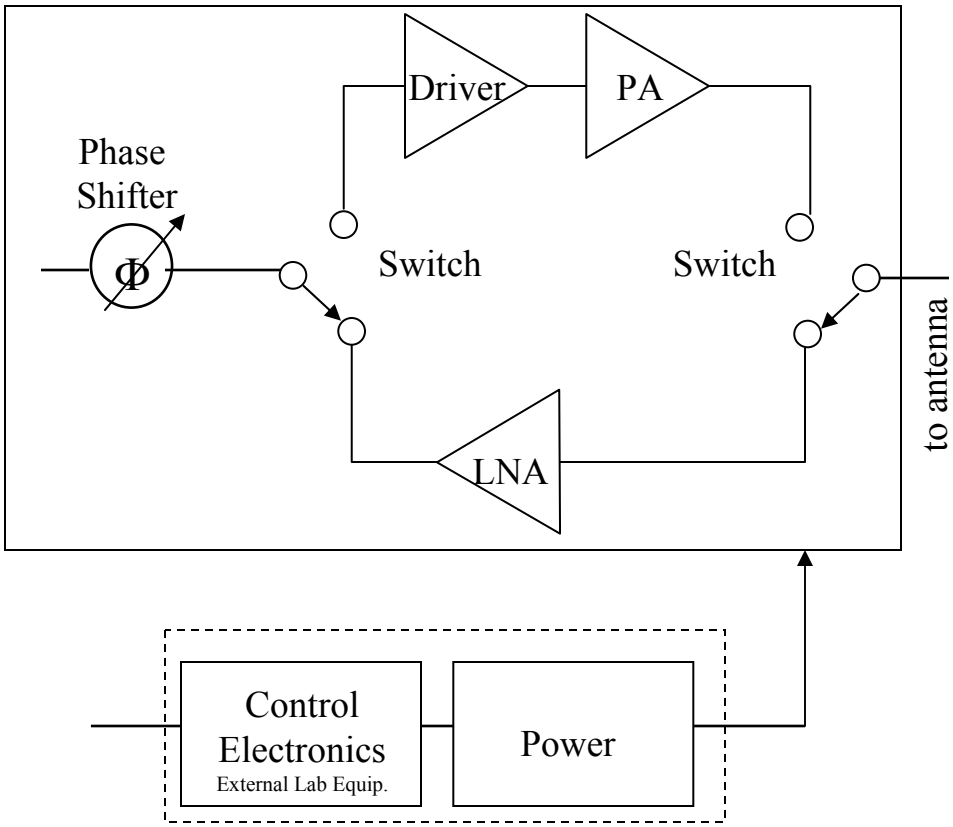
Far Field Pattern
Freq = 1.20000 GHz, Scan Angle = 0.000



Far Field Pattern
Freq = 1.20000 GHz, Scan Angle = 90.000

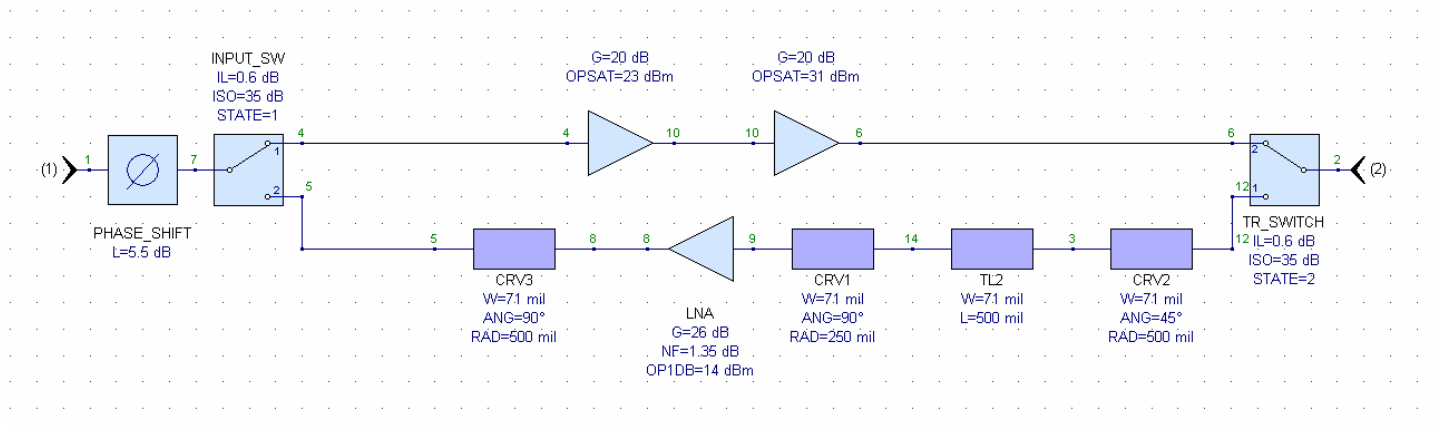


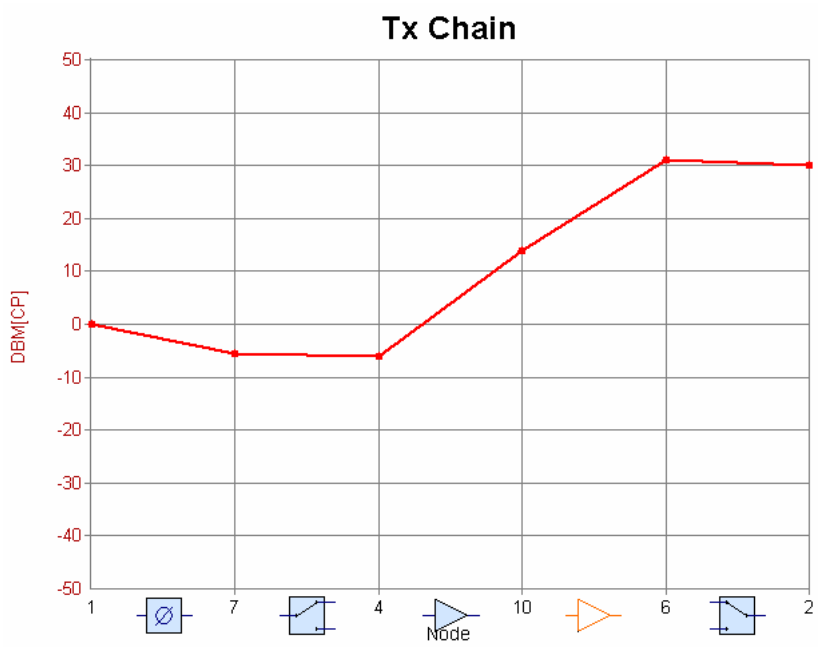
T/R Block Diagram

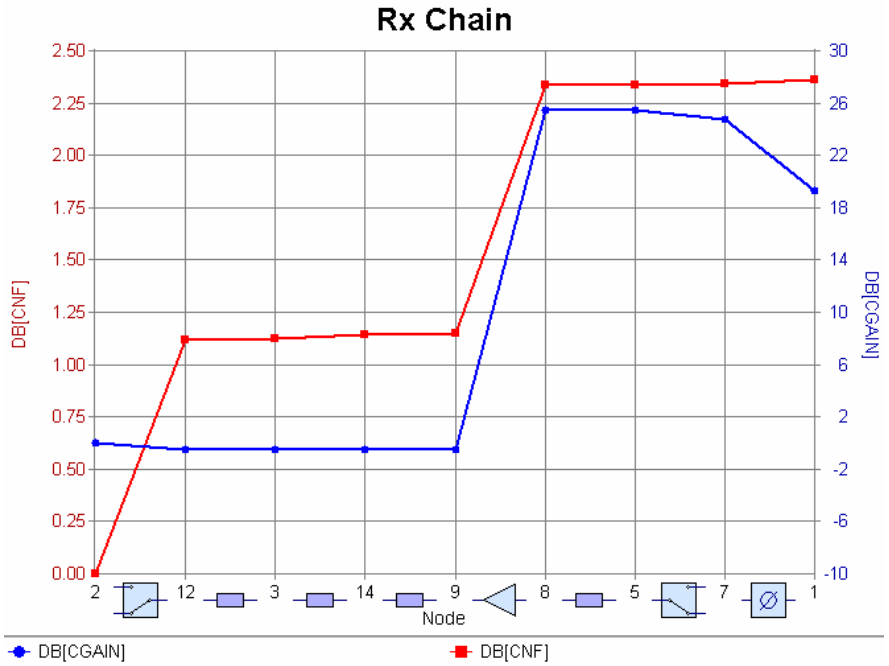


T/R Module Preliminary Specs	
Frequency:	1220 –1300 MHz
Bandwidth:	80MHz
Tx Peak Power:	5W (1.2W this design)
Tx Average Power:	1W
Duty Cycle:	1 to 20%
Max PRF:	200Hz (GEO) 2KHz (LEO)
Max Pulse width:	1000usec (GEO), 50-100usec (LEO)
Tx/Rx gain:	30/20dB
Phase Shifter Bits:	6bits
NF:	<3 dB

T/R Module Performance

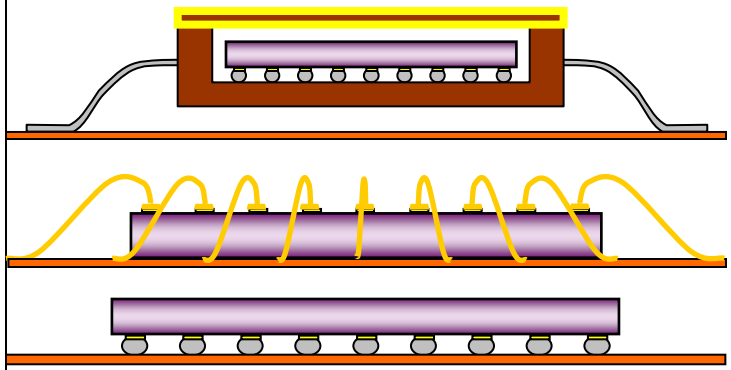


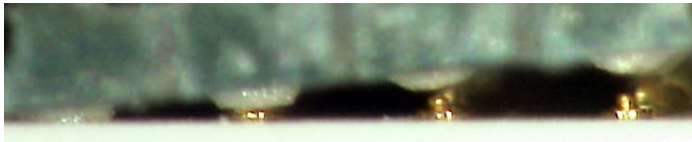


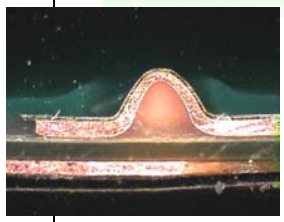


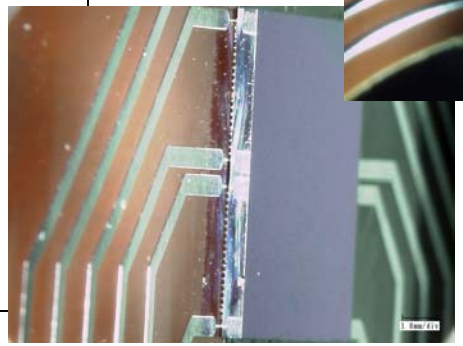
Attachment

- Attachment methods:
  - o Packaged
  - o Die
    - Wire Bond
    - Flip chip
      - ➢ Solder bump on electroless Ni/ flash Au
      - ➢ Au stud bump/conductive epoxy
      - ➢ Au stud bump/solder paste
      - ➢ Gold dot on flex
- Reliability:
  - – Thermal Cycle
  - – Mechanical
- Flip Chip attachment and reliability being investigations under a code R task.

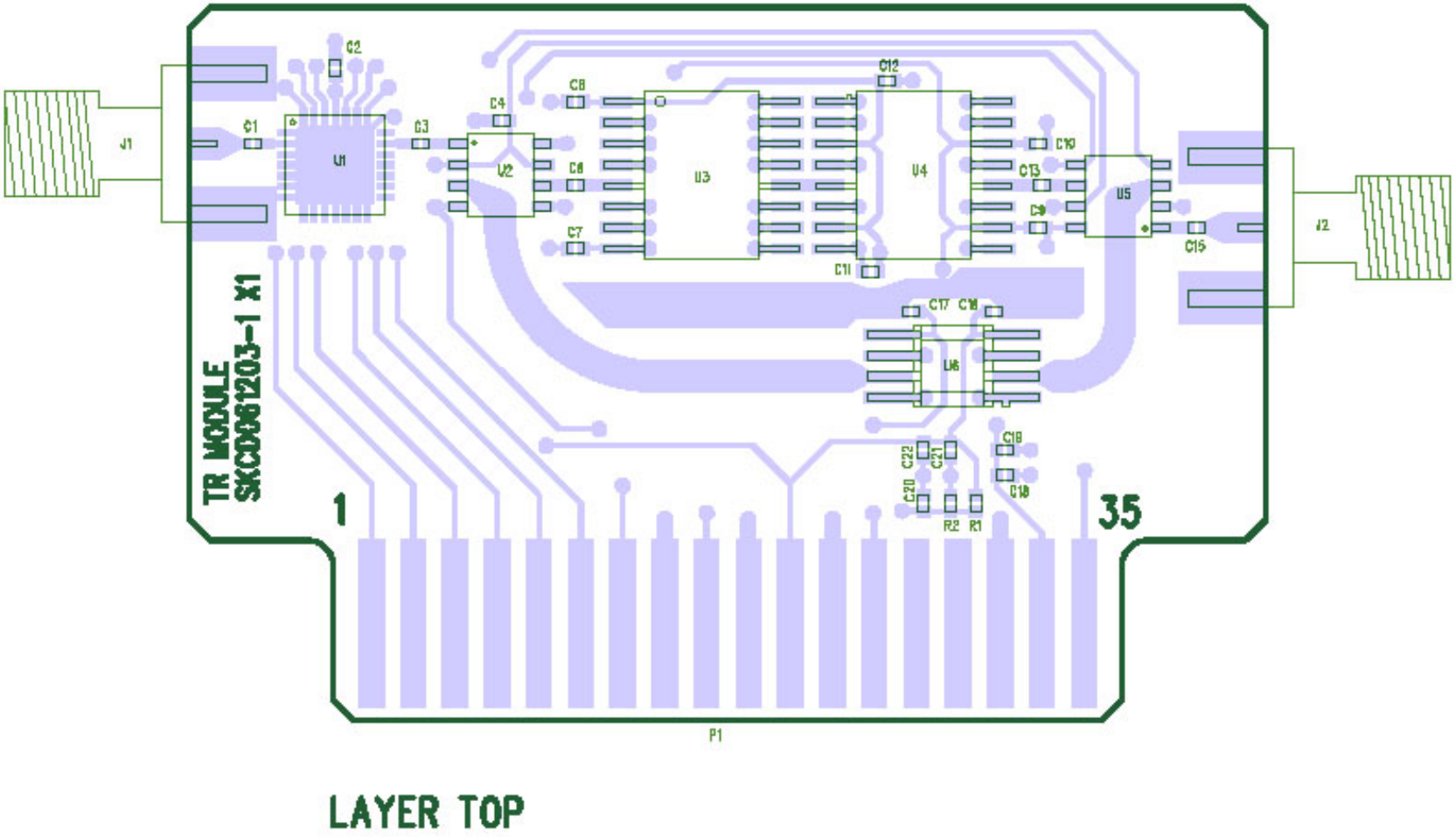




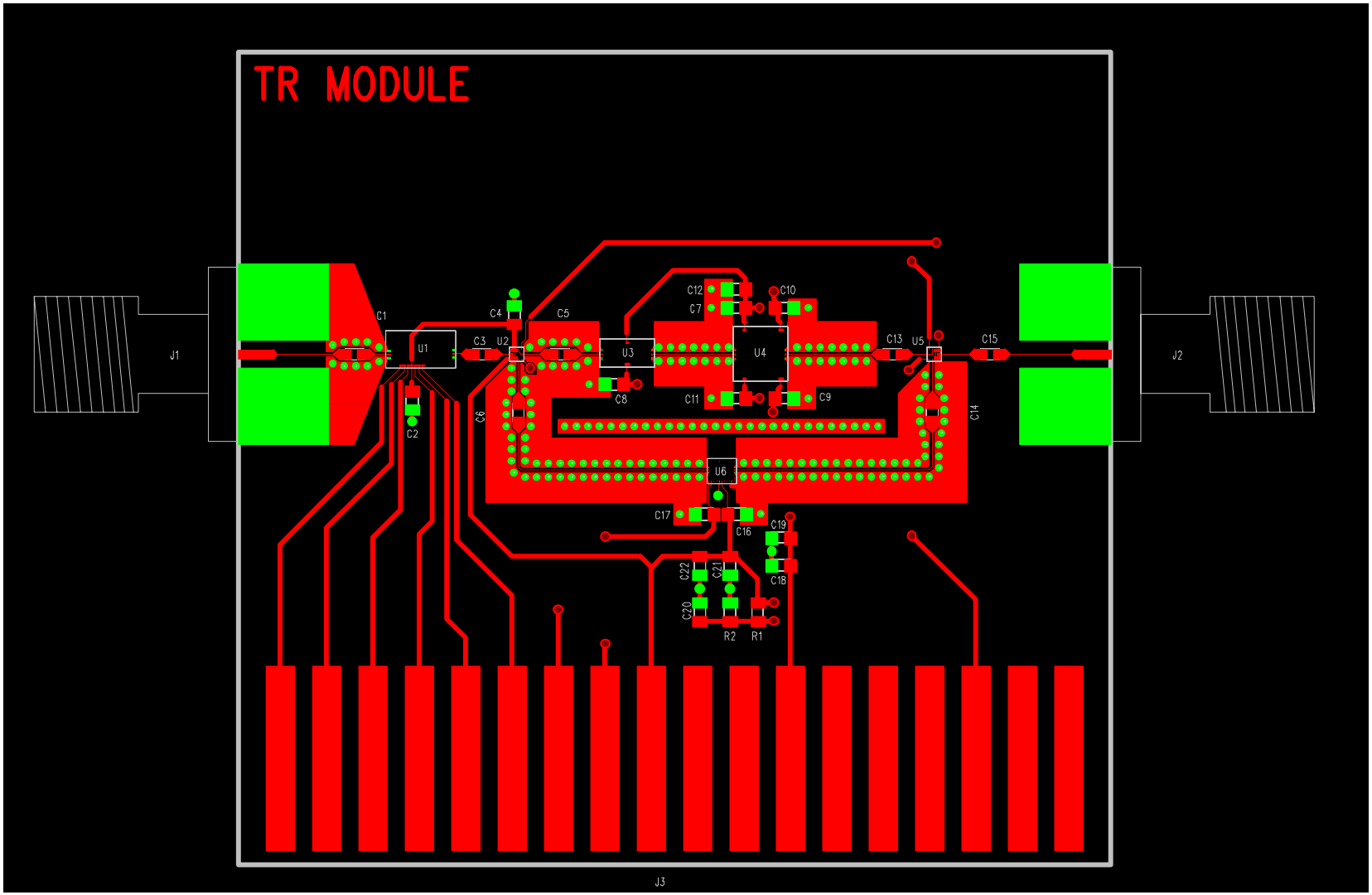




T/R Module Layout – Using Surface Mount Packages



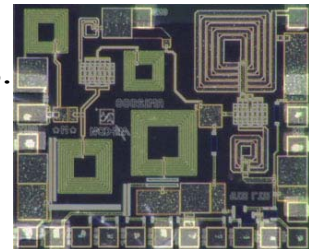
T/R Module Layout – Using Flip Chip Die



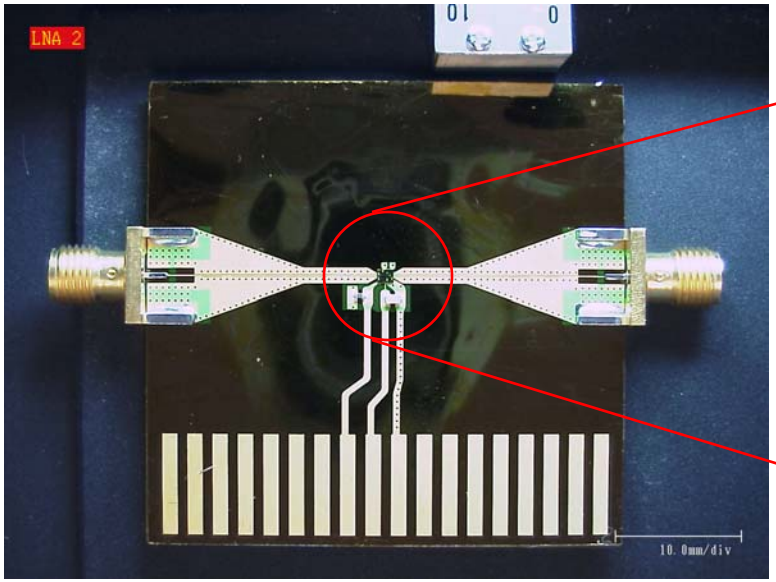
LNA Test Circuits

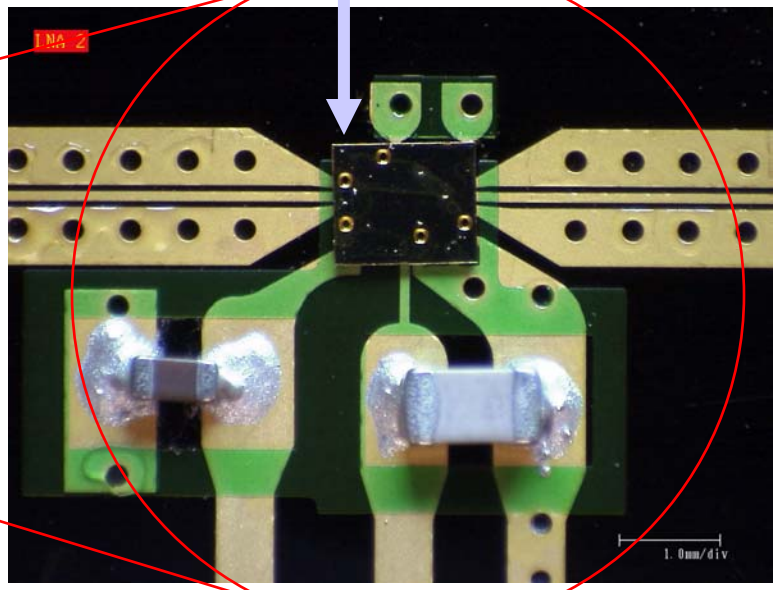
The LNA circuit was chosen for evaluating:
- Fabrication of the flex board
- Flip chip attachment of the LNA to the flex board
- RF functionality of the circuit on flex board

Problems:
- Problem w/flex boards. A new vendor is identified with better results.
- Flip-chip attachment process development is slow

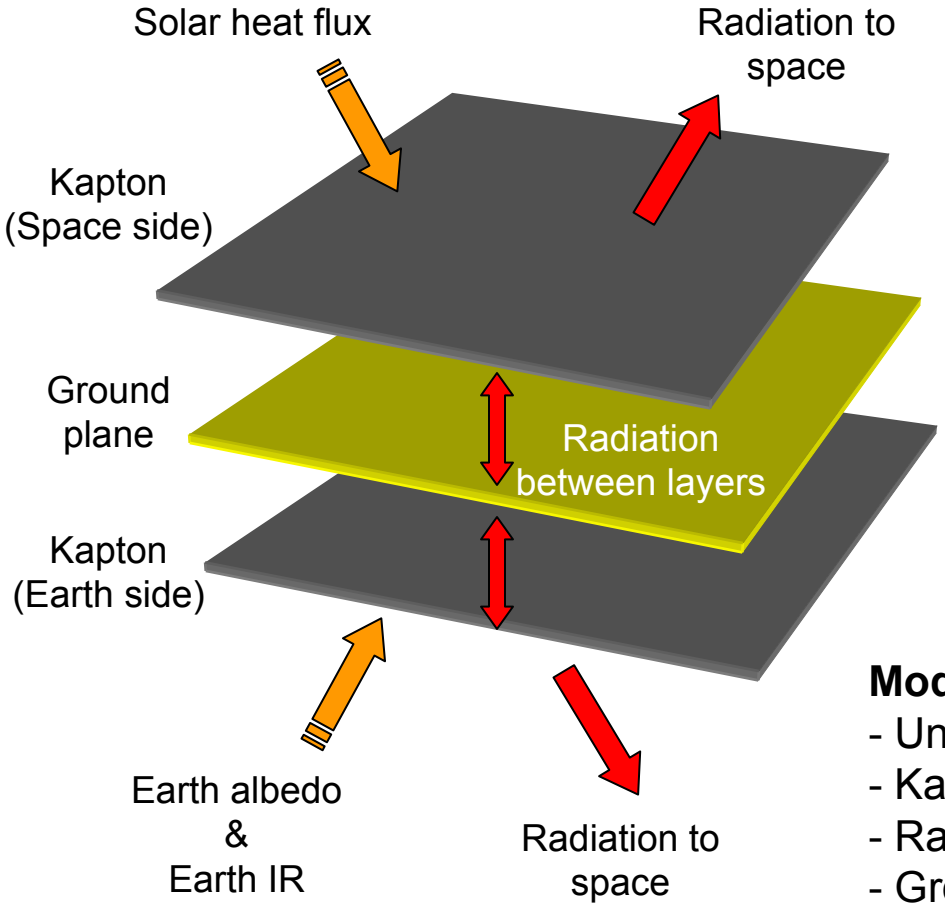


LNA Chip
MAAM12000





Thermal Simulations



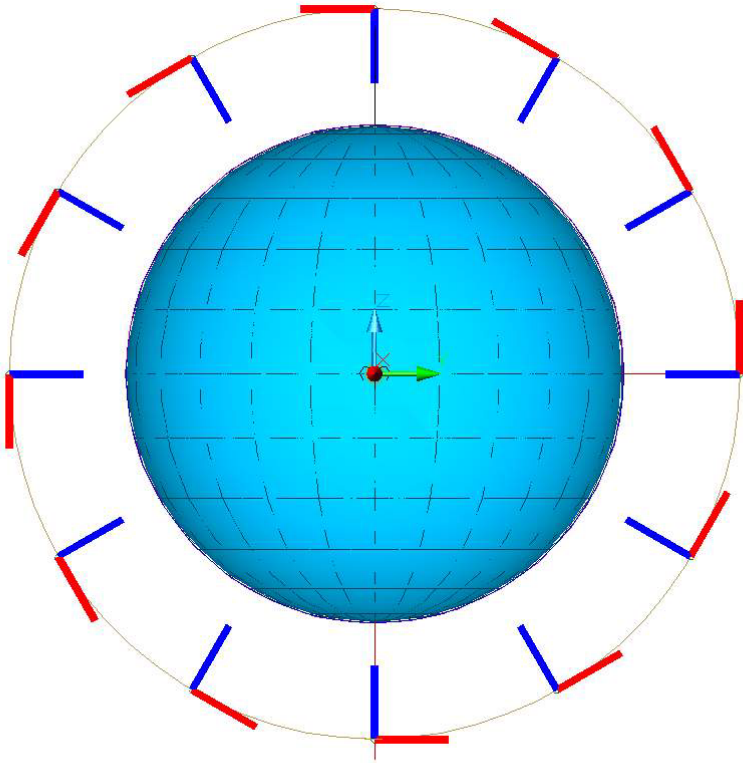
Model Assumptions:

- Unit Cell: 18x18 cm
- Kapton thickness: 2 mil
- Radiating patch: 10cmx10cmx7.5μm
- Ground plane: 2 mil Kapton + 7.5μm Copper
- Heat spreader: 40mmx40mmx50μm Copper
- T/R module: 5mmx5mmx0.5mm,
- T/R module dissipated power: 1.5 W
- Kapton: $\varepsilon = 0.75$, $\alpha = 0.35$
- Copper: $\varepsilon = 0.2$, $\alpha = 0.35$

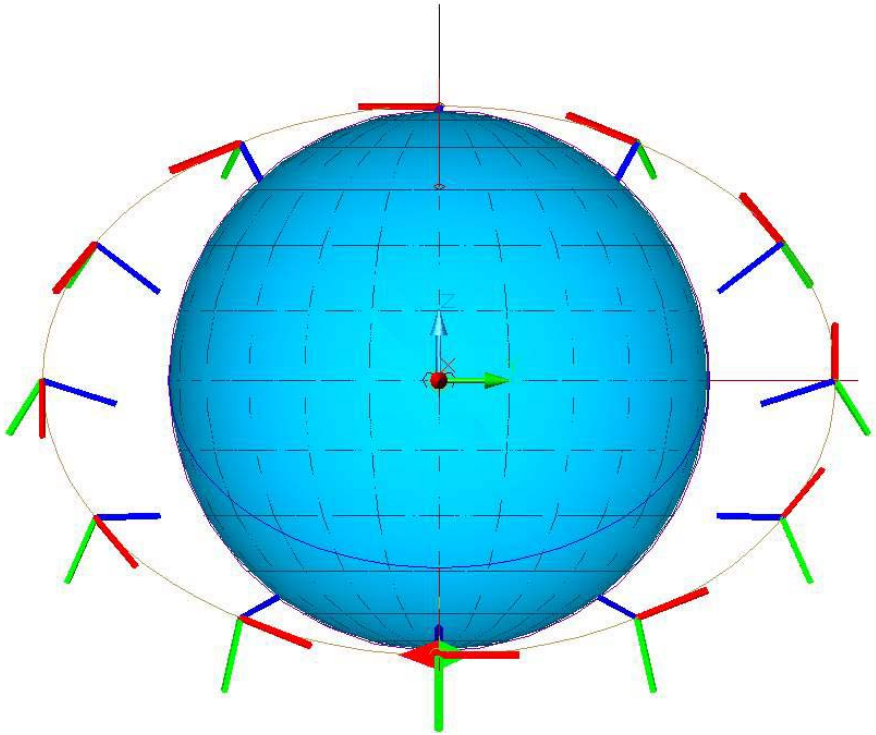
Thermal Simulations: Hot and Cold Cases in MEO

Satellite orbiting around the earth as seen from the Sun

Cold Case



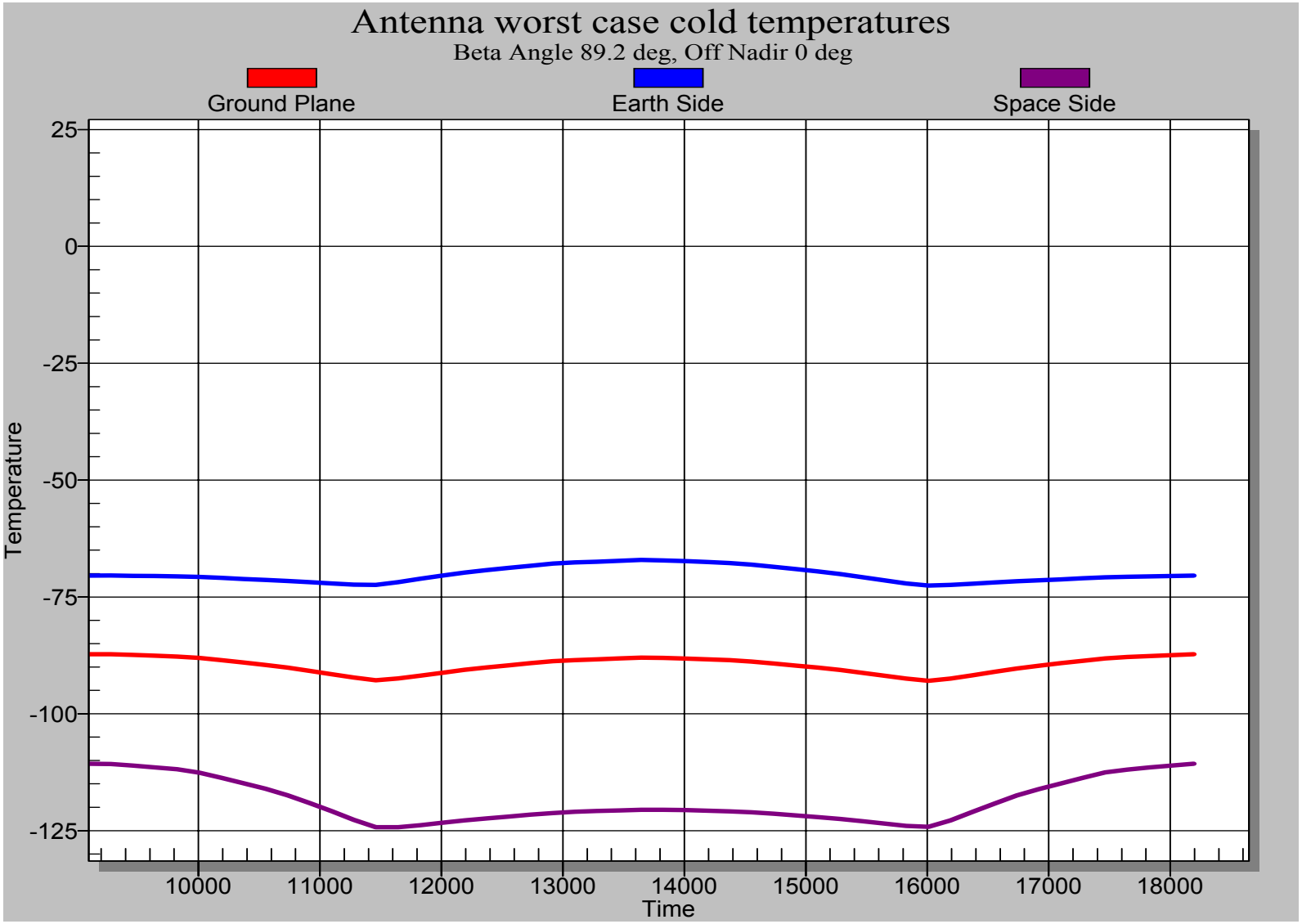
Hot Case



Plane of antenna

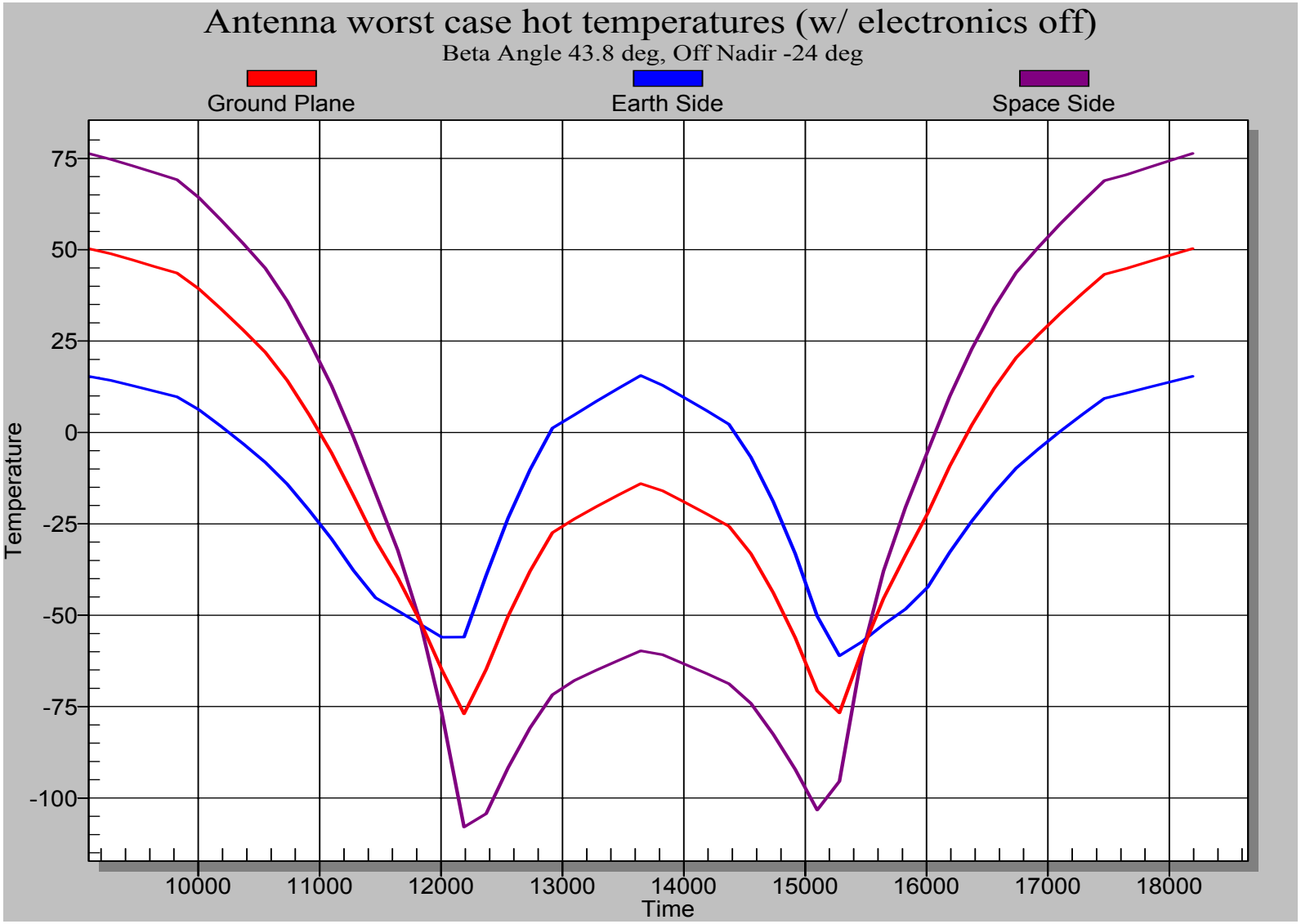
Antenna pointing direction

Antenna worst Case Cold Temperature Electronics turned off



Antenna worst Case Hot Temperature Electronics Turned off

California Institute of Technology

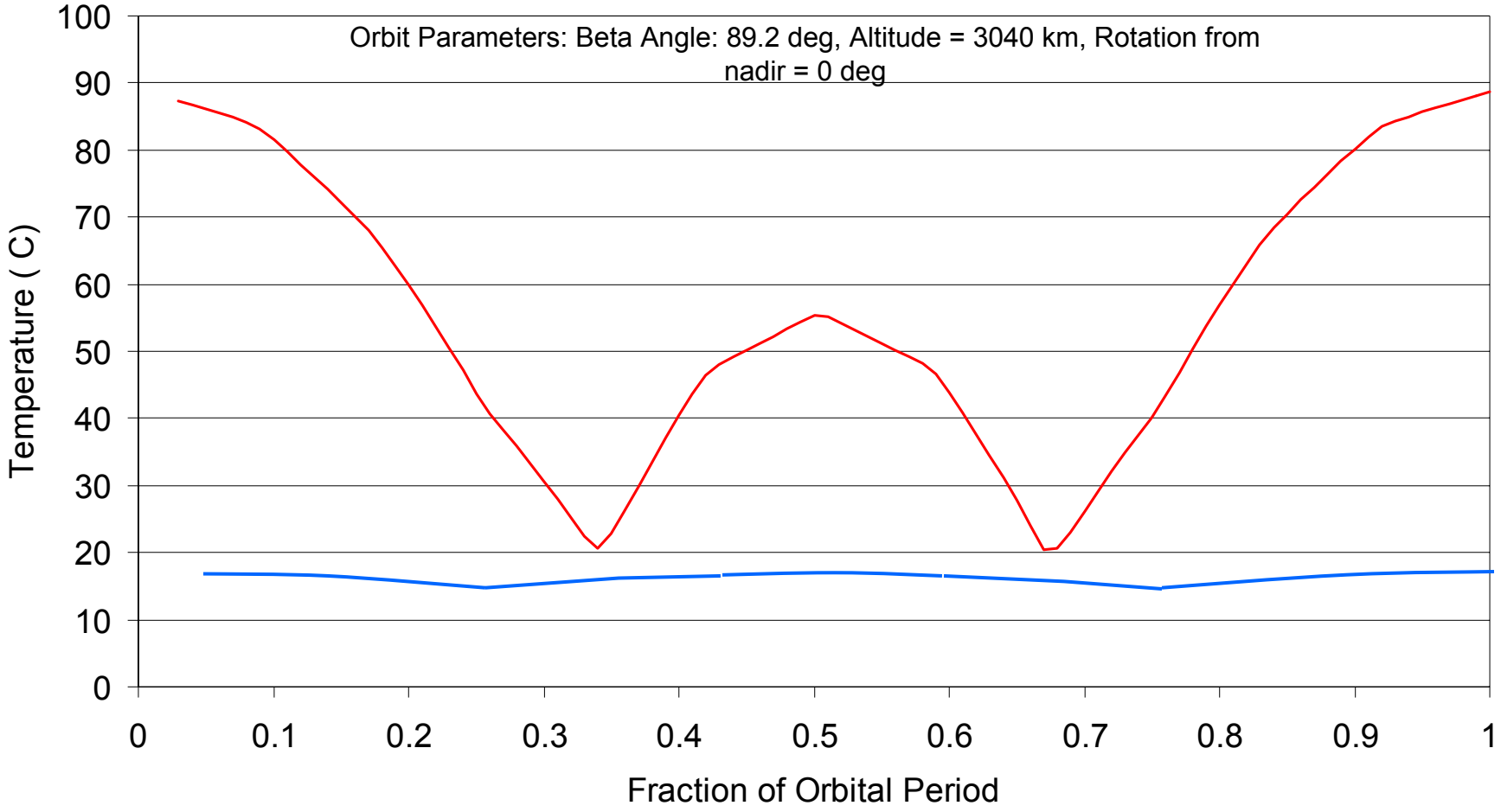


T/R Module Temperature – Cold/Hot

T/R Module Temperature During Orbit (Hot Case)

Orbit Parameters: Beta Angle = 43.8 deg, Altitude = 3040 km, Rotation from nadir = -24 deg

T/R Module Temperature During Orbit (Cold Case)



Issues, Concerns and Recovery Plans

Technical Difficulties:	**Recovery Plans:**
Reliable source of flex circuits effected quality of circuits	New vendor has been identified with satisfactory results
Problems with Flip chip attachment process	- New design with Packaged parts - Will postpone the use of flip chip attachment

Accomplishments and Future Plans

Accomplishments:
- Flip chip process under development.
- T/R (using packaged and die components) designed. Fabrication, testing and optimization underway.
- Antenna feed designed and tested. Optimization underway.
- Thermal simulation has started.

Plans for this year:
- Fabricate and test flex T/R using packaged parts
- Develop flip chip process and attempt flex T/R using flip chip die
- Continue with the thermal simulations

Possible longer term plans:
- Improve T/R circuit:
    - Increased transmit power (5W)
    - Include the digital controls
- Combine the T/R module with the feed and prototype a unit cell
- Demonstrate a 2x8 element prototype
- Integrate the heat spreader with the unit cell
- Test electrical/thermal performance of the T/R in simulated thermal environment